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The assessment of dust drift from pneumatic drills using static tests and in-field validation

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ABSTRACT

The utilization of dressed seed for sowing is a widespread practice to control certain pests with reduced doses of chemical products. The pneumatic drills used in maize (*Zea mays* L.) sowing have been shown to contribute to the dispersion of the abrasion dust produced by dressed seeds, causing environmental contamination. In recent years, several insecticides (neonicotinoids and fipronil) employed for maize dressing have been claimed to cause mortality and sub-lethal effects to honey bees (*Apis mellifera* L.). This paper reports a two-stage research study aimed at evaluating the amounts of dust emitted by a precision pneumatic drill during the sowing of maize dressed with clothianidin, fipronil, imidacloprid and thiamethoxam. In the first step, we assessed the dust drift in static tests performed in a simulated wind tunnel. Next, we compared the results with real sowing trials carried out in the field. The data were subjected to appropriate processing that provided a theoretical assessment of the spatial distribution of the pesticide concentration. The results demonstrated a good correspondence between the amounts of predicted drift at ground level during the static tests and the measured residues during the field trials. At the same time, no prediction was possible in terms of air concentrations of the active ingredient, suggesting that the dust drift in the air behaves differently from its deposition on the ground.

1. Introduction

Pneumatic precision drills (Fanigliulo and Pochi, 2011; Foqué et al., 2014) have a seed distribution system based on the vacuum effect created by a centrifugal fan. The sucked air is expelled through the fan opening, dragging with it abrasion dust and seed particles containing dressing (or coating) substances.

This feature is particularly relevant for its potential effects on honey bees (*Apis mellifera* L.) and other pollinating insects (Apenet, 2011; Pochi et al., 2012; Nuyttens et al., 2013) and for the potential exposure of the operators (Biocca et al., 2013). In recent years, scientists and beekeepers ascertained a relationship between honey bee mortality and decline and the sowing of maize (*Zea mays* L.) seeds dressed with neonicotinoid insecticides (imidacloprid, thiamethoxam, clothianidin) and fipronil (Greatti et al., 2006; Tremolada et al., 2010; Pistorius et al., 2010; Tapparo et al., 2012).

In the 2008, the Italian Government decided, as a precautionary measure, to suspend the use of all the four active ingredients (a.i.) registered for seed dressing (i.e., imidacloprid, thiamethoxam, clothianidin and fipronil) until new data on their toxicity will be available. Then, the same decision was taken by the European Commission in 2013.

Various test methods have been developed to verify the capability of drills to release abrasion dust during the sowing, mainly based on wind tunnel tests with reference powdery tracers capable to emulate the behavior of the abrasion dust (Rautmann et al., 2009; Manzone et al., 2014). Such methods are employed for drill classification according to national rules (Rautmann et al., 2009), in the absence of a classification method recognized as international standard.

We have developed a methodology based on static tests to obtain reproducible test conditions and comparable results. The methodology is based on the simulation of the sowing of maize dressed seed under artificial wind conditions.

The method was used for assessing the efficiency of drift reduction devices applied to the seeder in comparison with the

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emissions of the conventional machine (i.e., the same drill without the devices) (Apenet, 2011; Biocca et al., 2011). Through a data processing method of the results provided by the static tests, it is possible to foresee the dispersion of active ingredients that would occur in the field under similar atmospheric and operative conditions.

This paper provides evidence of the correspondence between the amount of predicted drift at ground level during static tests and the measured residues during field trials.

2. Materials and methods

2.1. Seed

The trials were carried out using commercial maize seed (Pioneer Hy-Bred PR32G44) dressed with four insecticides (Gaucho™, a.i.: imidacloprid; Poncho™, a.i.: clothianidin; Cruiser™, a.i.: thiamethoxam, Regent™, a.i.: fipronil) and a fungicide (Celest™, a.i.: fludioxonil and metalaxyl). According to the manufacturers, the application doses of a.i. were respectively equal to 1.00 mg seed^{-1} for imidacloprid, 1.25 mg seed^{-1} for clothianidin, 0.60 mg seed^{-1} for thiamethoxam and 0.50 mg seed^{-1} for fipronil. The seed was packed in sacks (25,000 seeds sack^{-1}).

The predisposition of seed to produce abrasion powder was assessed by means of the standard Heubach test (ESA STAT, 2011). According to the test method, the reference limit of dust produced is 3 g (100 kg)$^{-1}$. With the purpose of checking the stability of encrustation after the manipulations, the test was repeated at CRA-ING before the trials, always providing results below the reference limit.

2.2. Drills

A six-row precision pneumatic drill, “Gaspardo Magica”, was employed, with and without a device for the reduction of the drift based on air deflectors applied at the fan opening. The air deflectors can redirect the air outflow towards the soil, inside the furrows opened for seed deposition. The device consists of a steel frame applied at the fan opening, supporting four flexible plastic pipes that channel the air into the furrows opened by the two central sowing units. The device can be removed, restoring the “conventional drill” conditions and allowing the comparison between the conventional and modified machine. Before each test, the machine underwent accurate cleaning to eliminate the dust residues of the previously used seeds.

2.3. Test system at fixed point

The static tests were carried out in the workshop's porch of CRA-ING, a site protected by external influences and large enough to contain the machines (Fig. 1), as described in Biocca et al. (2011). In the test site, artificial wind conditions were produced by means of the axial fan (0.735 m diameter) of an orchard sprayer (Nobili Geo 75–600 T) powered by a 60 kW tractor at the P.T.O. speed of 540 min^{-1}. The air flow produced under these conditions was 22,900 m^3 h^{-1} (fan speed of 2160 rpm). Preliminary tests showed the repeatability and the constancy of wind conditions (speed and direction). The average wind speeds in the sampling site were 1.4 m s^{-1} at 0.5 m from the soil (min 0.0, max 2.6 m s^{-1}) and 1.8 m s^{-1} at 2.0 m from the soil (min 1.6, max 2.5 m s^{-1}).

The drill, suitably placed in the test area, operated the seed distribution “*sur place*” by means of a system allowing adjustment of the peripheral speed of the drill's driving wheel. The system consisted of an electric engine (power: 1.5 kW; maximum speed: 2600 rpm) connected to the driving wheel through a gear-reducer (transmission ratio: 40/1). An inverter (OMRON Varispeed V7) allowed adjustment of the speed of the electric engine and, consequently, of the peripheral speed of the driving wheel, on the desired value of 1.67 m s^{-1}.

In the test site, which resembled a wind tunnel, we have delimited a 22.5 m long sampling area, downwind with respect to the drill position. Along the sampling area, five series of Petri dishes, spaced 4.5 m, were placed; each series consisted of three Petri dishes spaced 1.5 m; therefore, a grid of 15 sampling points was arranged (Fig. 1). Before each test, the Petri dishes were filled with a 50% acetonitrile-water solution.

At the same time, three air samplers (TCR Tecora model “Bravo”) have been used for the detection of the air concentration of the a.i. Dust collection was obtained by means of 0.45 μm PTFE Millipore diskette filters (diameter 47 mm), placed at 5, 10 and 20 m from the drill. The sampling flow rate was 5 L min^{-1}; sampling duration was 20 min, to complete the air sampling 5 min after the end of the seed distribution. The test consisted in the sowing of one sack of seed (25,000 seeds), corresponding to a virtual sowed surface of 3333 m^2. Each trial was replicated three times for each investigated a.i.

2.4. Field tests

The trials were carried out in the experimental farm of CRA-ING (approximately 42°5′51.26″ N; 12°37′3.52″ E; 24 m a.s.l.) in 2010.

To operate at the same seed density of 75,000 seed ha^{-1}, the drill settings were the same as in the static tests,. During the trials, the main micrometeorological parameters were monitored (Table 1).

The tests were carried out sowing 3 ha rectangular plots (~140 × 215 m). The evaluation of the dust deposition at ground level was made using the same types of samplers as for the tests at fixed point (Petri dishes with 50% acetonitrile/water solution). The sampling area corresponded to a 20 m wide belt around the field perimeter. The dust ground deposition was observed on all plot sides (North, South, East and West) with the aim of capturing the settling dust at ground level independent of the possible changes in wind direction during the trials. A series of three Petri dishes spaced 1.5 m apart were placed on each side at 5, 10 and 20 m from the field edge; hence, a total of 36 sampling points was obtained (Fig. 2).

As regards the air sampling, the three air pumps were placed at 5, 10 and 20 m from the field edge, on the plot side that was downwind at the beginning of the test. One field trial was conducted for each investigated a.i.

2.5. Determination of active ingredients

The determination of active ingredients in the samplers was carried out at CRA-PAV. Active substances were extracted from the samples with acetonitrile. Solutions were vibrated in an ultrasonic bath for 10 min and then filtered with HPLC (High-Performance Liquid Chromatography) 0.45 μm filters. The analyses were carried out by means of HPLC coupled to an MSD (Mass Spectrometry Detector) operating with an ES+ (Electrospray Ionisation Interface, positive mode), and the relative methods were validated in compliance with GLP (Good Laboratory Practice) procedures. The following instruments were used: Waters Alliance 2695 Separation Module and 2695 Autosampler; Micromass 4 micro Triple Quadrupole Mass Spectrometer with Electrospray Ionisation (ESI) probe; and Waters X-Terra MS column C18, 5 μm 150 × 4.6 mm, flow 0.3 mL min^{-1}, gradient elution with water (0.1% acetic acid) and 10% acetonitrile (0.1% acetic acid) up to 90%, in MRM (Multiple Reaction Monitoring) mode. The mass spectrometer detector was tuned in the MRM mode at the maximum sensitivity for each of the parent